
APPLICATION FOR UNITED STATES LETTERS PATENT

for

ANTENNA DIVERSITY RECEIVER

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ANTENNA DIVERSITY RECEIVER

FIELD OF INVENTION

2 This invention relates to an antenna diversity receiver which has a selective
switching circuit for coupling one of a plurality of antennas to a RF receiver input, as well
4 as a multipath detector for controlling the selective switching circuit.

BACKGROUND OF INVENTION

6 The reception of a wanted RF broadcast transmitter signal may be disturbed or
otherwise deteriorated by various phenomena, such as multipath reception and/or adjacent
8 channel interferences. In general, multipath reception is caused by signal reflections at
and/or against environmental physical obstacles such as mountains, trees, buildings,
10 fences and the like. Due to such signal reflections a RF broadcast signal may arrive at a
certain reception location through various different signal paths which result in different
12 amplitude and phase conditions. The summation of these multipath signals at the antenna
of the receiver results in unpredictable signal amplitude and/or phase distortions. These
14 conditions often effectuate partial or complete cancellation of the useful RF reception
signal. These signal cancellations, hereinafter also being referred to as signal dips,
16 strongly depend on the RF carrier frequency of the received RF broadcasting signal and
on the location of reception.

18 The signal dips severely deteriorate the wanted RF broadcasting signal and

therefore also the overall signal reception quality. However, a relatively small shift in the antenna position may strongly improve signal reception quality. This solution is used in so-called antenna diversity receivers used with mobile FM receivers to avoid reception of multipath distorted RF signals. Such antenna diversity receivers are provided with two or more mutually spaced apart antennas coupled to a RF input of a receiver. Only the antenna having best local receiving conditions with respect to the other antenna(s) is actually connected to the RF receiver input. This antenna is hereinafter referred to as an actual antenna and is effective in the reception and supply of the wanted RF broadcasting signal to the receiver as long as the multipath distortion at the actual antenna remains smaller than a certain predetermined multipath threshold level. As soon as the received multipath distortion exceeds the predetermined multipath threshold level, a change of the RF signal supply to the receiver from the actual antenna to another antenna positioned at a location with better receiving conditions, is initiated. The receiver is thus continuously optimized for minimum multipath reception.

However, inherent to the antenna diversity feature are short interruptions in the RF signal supply to the receiver during the antenna change over or switching action. Due to the delay between the occurrence of an actual multipath caused signal dip and the detection thereof, the RF signal interruptions may be detected as being caused by multipath effects, and may initiate a subsequent false antenna switching action. The false antenna switching action may in its turn be detected as a multipath originated signal dip

initiating a further false antenna switching action with an oscillating effect as a result. To
2 reduce the risk of oscillating antenna switching actions, known antenna diversity
receivers using Philips' TEA 6101 model antenna diversity integrated circuit are provided
4 with means to disable any switching action following a preceding switching action within
a certain predetermined fixed time period.

6 This known measure however, is not effective in receivers with dynamic IF
selectivity, such as receivers with adjacent channel suppression. As mentioned above,
8 adjacent channel interferences are another important source of signal distortion and are
usually caused by FM radio broadcast signals modulated on a carrier positioned in
10 frequency adjacent to the carrier frequency of a wanted FM radio broadcast signal. Due
to peak values in the FM modulation signal, these adjacent channel FM radio signals may
12 temporarily exceed the allocated channel bandwidth breaking through into the frequency
range of the wanted FM radio broadcast signal. Adjacent channel suppression receivers
14 suppress such adjacent channel interferences by varying the bandwidth of the variable
bandwidth intermediate frequency (IF) selector circuits dependent on the deviation of the
16 adjacent channel signal within the frequency range of the wanted FM radio broadcast
signal. The larger the deviation, the smaller the bandwidth of the variable bandwidth
18 intermediate frequency (IF) selector circuit. The dynamically varying IF selectivity thus
effectuates a suppression of the adjacent channel interferences.

20 There is thus a need for a receiver which combines the benefits of the antenna

diversity feature with those of the dynamic IF selectivity feature while preventing
unwanted effects from occurring. There is a further need for an improved performance
antenna diversity receiver.

SUMMARY OF THE INVENTION

These needs may be addressed by the present invention which is may be embodied
in an antenna diversity receiver having antenna selective switching means for coupling
one of a plurality of antennas to a RF receiver input, and a multipath detector for
controlling the antenna selective switching means. The receiver is characterized by
switching disabling means for automatically disabling the switching means when the
signal delay between the occurrence of multipath distortion in the RF reception signal and
the activation of the switching means exceeds a predetermined critical signal delay value.
The present invention is based on the recognition that in an antenna diversity receiver the
delay between the actual occurrence of a multipath caused signal dip and its detection is
determined by the receiver's IF selectivity.

In a receiver with dynamic IF selectivity, the IF bandwidth is variable, therewith
causing the delay to vary as well such that the smaller the IF bandwidth the longer the
delay and vice versa. However, the longer the delay, the greater the risk of oscillating
false antenna switching actions. By introducing the delay as a new parameter for
disabling antenna switching actions in accordance with the invention, any antenna

switching action is disabled when and for the time the delay exceeds the predetermined critical value. This allows for a combination of the features of antenna diversity and dynamic IF selectivity, while preventing antenna switching actions from oscillating.

Preferably, the antenna diversity receiver is characterized by an adjacent channel detector coupled to a bandwidth variable intermediate frequency (IF) circuit. The predetermined critical signal delay value defines a critical bandwidth for the bandwidth variable IF circuit. The switching means is automatically disabled when the bandwidth of the bandwidth variable IF circuit is smaller than the critical bandwidth. This measure is based on the above mentioned correspondence between the IF bandwidth and the delay between the actual occurrence of a multipath caused signal dip and the detection of it. The bandwidth of the bandwidth variable intermediate frequency (IF) circuit is accurately reflected in the output signal of the adjacent channel detector. This allows for a simple implementation of the invention.

A further preferred embodiment of the antenna diversity receiver is characterized by a threshold circuit coupled between an output of the adjacent channel detector and a control input of the switching disabling means. The threshold circuit compares the output signal of the adjacent channel detector with a threshold value corresponding to the critical bandwidth and supplies a switching disabling control signal to the switching disabling means when the output signal of the adjacent channel detector effectuates a bandwidth smaller than the critical bandwidth.

With a simple adjustment of the threshold voltage, the critical bandwidth can be set at a value preventing the antenna switching actions from oscillating and providing an effective adjacent channel suppression on the other hand. An antenna diversity receiver, which is provided with a fixed timer circuit introducing a fixed switching disabling period following each antenna switching action in accordance with the invention is preferably characterized by the bandwidth variable intermediate frequency (IF) circuit effecting a signal delay at the critical bandwidth corresponding to the fixed switching disabling period.

Such a fixed timer circuit is included in the Philips' TEA 6101 antenna diversity integrated circuit and may well be combined with the antenna switching disabling functionality initiated by the above switching disabling control signal. The use of the fixed switching disabling period as a reference for the determination of the critical bandwidth avoids the occurrence of antenna switching oscillations throughout the complete bandwidth control range of the bandwidth variable intermediate frequency (IF) circuit.

In practice the fixed switching disabling period following each antenna switching action in the Philips' IC TEA 6101 is 20 usec., defining the critical bandwidth to be substantially within the range between 40 and 50 KHz.

Another preferred embodiment of antenna diversity receiver provides for a simple combination of both the adjacent channel suppression feature with the antenna diversity

feature is characterized in providing the adjacent channel detector with a multiplex input
coupled to an output of the demodulator for detecting adjacent channel reception at the
occurrence of both an amplitude variation in the IF signal level as well as distortion
components in the demodulator output signal.

In yet another preferred embodiment, the plurality of antennas includes an antenna
for receiving radio broadcast RF signals as well as an antenna for receiving
telecommunication RF signals.

It is to be understood that both the foregoing general description and the following
detailed description are not limiting but are intended to provide further explanation of the
invention claimed. The accompanying drawings, which are incorporated in and constitute
part of this specification, are included to illustrate and provide a further understanding of
the method and system of the invention. Together with the description, the drawings
serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWING

FIG.1 shows an antenna diversity FM receiver according to one embodiment of
the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

While the present invention is capable of embodiment in various forms, there is

shown in the drawings and will hereinafter be described a presently preferred
embodiment with the understanding that the present disclosure is to be considered as an
exemplification of the invention, and is not intended to limit the invention to the specific
embodiment illustrated.

FIG. 1 shows an antenna diversity FM receiver having first to fourth antennas 2,
4, 6 and 8 coupled through an antenna selective switching circuit 10 to a RF receiver
input circuit 12. The RF receiver input circuit 12 is followed by a mixer device 14 which
is supplied with a tunable local oscillator signal from an oscillator circuit 16, a variable
bandwidth intermediate frequency (IF) selector circuit 18 (selective IF circuit), a IF
amplifier 20, an FM demodulator 22 and a baseband modulation signal processor 24. The
baseband modulation signal processor 24 is coupled to stereo left and stereo right signal
reproducing circuits 26 and 28.

The signal processing in the antenna diversity receiver described so far is known.
A RF broadcasting signal is received at one of the first through fourth antennas 2, 4, 6 and
8. In the embodiment shown, the third antenna 6 is the actual antenna. The third antenna
6 is supplied via the antenna selective switching circuit 10 and a RF receiver input
terminal to the RF receiver input circuit 12 for broadband selection and amplification of
the RF broadcasting signal. The output signal of the RF receiver input circuit 12 is then
mixed in the mixer device 14 with the tunable local oscillator signal for a first
demodulation of a wanted RF broadcast signal into an intermediate frequency (IF) signal.

This IF signal is filtered in the selective IF circuit 18, subsequently amplified by the IF
2 amplifier 20 and demodulated by the FM demodulator 22 into a baseband modulation
signal which is a stereo multiplex (MPX) signal. The MPX signal is further processed in
4 the processor 24 to obtain stereo left and stereo right signals to be converted into acoustic
signals in the stereo left and stereo right signal reproducing circuits 26 and 28.

6 The antenna diversity receiver also includes a multipath detector 30 for detecting
multipath distortion in the received RF signal. The detection of multipath distortion is
8 based on two criteria: the occurrence of a (fast) amplitude dip in the level of the IF signal
and the occurrence of distortion components occurring within the frequency range of the
10 baseband modulation signal above the frequency spectrum of the MPX signal. The first
and second input terminals of the multipath detector 30 are therefore coupled respectively
12 to an output of the selective IF circuit 18 and to an output of the FM demodulator 22. If a
IF signal dip is detected to occur simultaneously with distortion components within the
14 frequency range of the baseband modulation signal, then the multipath detector 30
supplies a switching control signal to a switching control signal input terminal 31 of an
16 antenna switching control device 32. This causes the antenna selective switching circuit
10 to change over reception from the antenna 6 which is the
18 actual antenna up to this switching action, to another antenna, having better receiving
conditions than the antenna 6. In this example, the antenna 8 is selected (the connection
20 to the RF receiver input circuit 12 is not shown).

The next multipath caused signal dip detected will initiate a subsequent antenna switching action as described above. In receivers using Philips' TEA 6101 antenna diversity integrated circuit the antenna switching control device 32 has a disabling circuit 33 which prevents any antenna switching action from being followed by a subsequent antenna switching action within a fixed time period of 20 usec. These time periods are referred to as fixed switching immunity periods. The antenna switching disabling circuit 33 has a timer circuit (not shown) using a counter, which is set to start counting monotonously up or down at the occurrence of each switching control signal and stops counting after the fixed time period of 20 usec. This provides immunity from switching control signals during counting and prevents switching actions during these fixed switching immunity periods from occurring.

The antenna diversity receiver is provided with an adjacent channel detector 38 functioning as bandwidth control which has an input coupled to an output of the FM demodulator 22. The channel detector 38 also has an output coupled to a bandwidth control input of the selective IF circuit 18. This output varies the bandwidth dependent on adjacent channel interferences, such that the bandwidth of the selective IF circuit 18 is smaller, the more the adjacent channel signal is overlapping or trespassing the frequency area of the wanted RF signal. The interferences caused by such adjacent channel signals are thereby reduced. For a more detailed description of the functioning of the adjacent channel feature in suppressing adjacent channel interferences, reference is made to US

Patent No. 4,907,293 hereby incorporated by reference.

2 In addition to the fixed switching immunity periods the receiver is also provided
with an immunity for switching control signals from the multipath detector 30 when and
4 for the time, the bandwidth of the selective IF circuit 18 is smaller than a certain critical
bandwidth value. To avoid switching actions from oscillating at any bandwidth of the
6 selective IF circuit 18 within its entire bandwidth variation range, the length of the fixed
switching immunity periods following each antenna switching action provided by the
8 timer circuit is used to determine the critical bandwidth value, such that the bandwidth
variable intermediate frequency (IF) circuit will effect a signal delay at the critical
10 bandwidth corresponding to the fixed switching disabling period. At a length of the fixed
switching immunity periods of 20 usec. the critical bandwidth value, which is referred to
12 as the predetermined threshold value of the IF selectivity bandwidth, will be substantially
within the range between 40 and 50 KHz.

14 Therefore the receiver has a threshold circuit 36 coupled between an output of the
adjacent channel detector 38 and a control input 35 of the antenna switching disabling
16 circuit 33 for comparing the output signal of the adjacent channel detector 38 with a
threshold value corresponding to the critical bandwidth value and for supplying a
18 switching disabling control signal to the antenna switching disabling circuit 33, when the
output signal of the adjacent channel detector 38 effectuates a bandwidth smaller than the
20 critical bandwidth value. The threshold value is set with a well chosen predetermined

threshold voltage V_{th} supplied from a threshold voltage input terminal 34 to the threshold
2 circuit 36.

It will be apparent to those skilled in the art that various modifications and
4 variations can be made in the method and system of the present invention without
departing from the spirit or scope of the invention. For example, the plurality of antennas
6 may include an antenna for receiving radio broadcast RF signals as well as an antenna for
receiving telecommunication RF signals. The present invention is not limited by the
8 foregoing descriptions but is intended to cover all modifications and variations that come
within the scope of the spirit of the invention and the claims that follow.